WPS 2936

POLICY RESEARCH WORKING PAPER 2936

Industrial Ownership and Environmental Performance

Evidence from China

Hua Wang
Yanhong Jin

The World Bank
Development Research Group
Infrastructure and Environment
December 2002

Abstract

Wang and Jin explore the differences in pollution control performance of industries with different types of ownership in China—state-owned (SOE), collectively- or community-owned (COE), privately owned (POE), companies with foreign direct investment (FDI), and joint ventures. About 1,000 industrial firms in three provinces of China were surveyed, and detailed 1999 firm-level information was obtained.

The authors analyzed the differences between firms in receiving and reacting to environmental regulatory enforcement, community pressure, environmental services, as well as in the firm's internal environmental management among the different types of ownership. The authors also conducted econometric analyses on the determinants of pollution discharge performance.

The results show that foreign direct investment and collectively-owned enterprises have better environmental performances in terms of water pollution discharge intensity, while state-owned enterprises and privately owned enterprises in China are the worst performers. The results also suggest that collectively-owned enterprises in China do internalize environmental externalities.

This paper—a product of Infrastructure and Environment, Development Research Group—is part of a larger effort in the group to study environmental regulation in developing countries. The study was partially funded by the Bank's Research Support Budget under the research project "Understanding and Improving Environmental Performance of China's Township and Village Industrial Enterprises." Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Yasmin D'Souza, room MC2-622, telephone 202-473-1449, fax 202-522-3230, email address ydsouza@worldbank.org. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. Hua Wang may be contacted at hwang1@worldbank.org. December 2002. (28 pages)

Industrial Ownership and Environmental Performance: Evidence from China[1]

Hua Wang
Development Research Group
World Bank

&

Yanhong Jin
Department of Agricultural and Resource Economics
University of California, Berkeley

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[1] Corresponding address: Hua Wang, MC2525, World Bank, 1818 H St., N.W., Washington, DC 20433, USA; Email: HWANG1@worldbank.org.

This paper is a product of one research project on China environmental policy partially funded by a World Bank research grant (RF-P065614). Many people participated in this research project. Major participants of the project include Jun Bi, Fengzhong Cao, Susmita Dasgupta, Dongmei Guo, Benoit Laplante, Genfa Lu, Guangshou Peng, David Wheeler, Zhifeng Yang, Guomei Zhou, as well as the authors of this paper. The authors would like to thank sincerely for contributions made by the project participants.

I. Introduction

This paper explores the relationship between industrial ownership and environmental performance. Developing countries have been witnessing reforms of state-owned enterprises (SOE), a rapid growth of private sectors (POE) and a steady increase of foreign direct investment. The economic performance of SOEs deteriorated in most countries in the 1970s and 1980s as global markets fueled competitive pressures (World Bank, 1996)[2]. The poor performance and relatively decreasing impact on the national economy of SOEs have been driving many governments to explore new ways for their SOEs to be re-organized, governed and operated. Three main avenues, corporation and restructuring, bankruptcy, and divestiture, have been implemented to raise the efficiency and profitability of their SOEs. The belief is that with more efficient resource allocation and better business performance of private sectors, privatization is being used in most of developing countries in order to promote economic growth in the last few decades (Frydman et al, 1997; Boardman and Vining, 1989; Claessens et al, 1997; World Bank, 1991).

The question then is whether this global privatization process is good for the environment. While private sectors are solely profit oriented, public sectors such as SOEs normally take more social impacts into their decision making processes. Therefore, while economically inefficient, SOEs' environmental performances could be theoretically better than the private sectors', others being equal.

Besides SOEs and POEs, countries such as China are also practicing another ownership structure, which is of collectively or community owned (COE)[3]. While responding to the market, COEs are supposed to internalize their environmental externalities for the local communities,

[2] World Bank (1996) summarized the performance of some developing countries as follows: (1) from 1985 to 1991, SOEs in Turkey on average earned only half as much as the largest 500 private industrial enterprises in Turkey; (2) in Viet Nam, there were 12000 SOEs existing in 1990. But 2000 SOEs had ceased operation or been liquidated, another 3000 had been merged, and 20% of remaining SOEs were estimated to be losing money in 1994; (3) in Kazakhstan the gross SOE losses rose from 14.1% of GDP in 1992 to 23.7% of GDP by 1993; and (4) the loss of SOEs in Argentina reached 9% of GDP in 1989 while SOEs's share of total public debt stood at 50%.
[3] Those enterprises are called "township and village industrial enterprises" or TVIEs in China.

while SOEs are supposed to internalize their externalities for the whole nation. Therefore, the environmental performance of COEs should also be better than that of POEs.

There are few systematic studies on the relationship between the ownership structure and environmental performance. To fill this gap, this study selects three regions in China - Danyang of Jiangsu Province, Liupanshui of Guizhou Province and Northern Tianjian Municipality, where plant-level surveys and plant manager interviews were conducted. All major industrial firms in each region were included in the sample. Detailed plant-level information such as production, material inputs, employment, pollution discharges and emissions, compliance with standards, pollution levies and fines paid, environmental inspections and complaints received, etc., in the year of 1999, were collected. Answers to the questions related to plant operation, perception of environmental quality, pollution control effort of the plant and the government, effectiveness of different policy instruments and enforcement efforts, community pressure, environmental services and markets, internal environmental management, etc. were received from plant managers.

Five different types of ownership in China – SOE, COE, POE, foreign directly invested (FDI) companies as well as joint ventures, were analyzed in this study. Analyses focused on the differences in receiving and reacting to environmental regulatory enforcement, community pressure, environmental services as well as in firm's internal environmental management among different types of ownership. Econometric analyses were also conducted on the determinants of industrial pollution discharge intensity. The results show that FDIs and COEs have better environmental performance, implying that COEs do internalize their environmental externalities, because otherwise, the environmental performance of COEs should be worse than that of POEs.

This paper is organized as follows. The next section reviews previous studies conducted in this area and presents a theoretic analysis of how ownership can affect a company's environmental performance. Section III provides some background information about China's industrial pollution control, the survey design and implementation, as well as the survey results. Section IV provides econometric analyses of industrial environmental performances, and Section V concludes the paper.

II. Ownership and Environmental Performance

2.1 Previous Research

Previous studies on the relationship between ownership structure and the environment have focused on the following issues:

2.1.1 Economic Efficiency

Private sectors may have higher efficiency in resource utilization. They may produce less pollution with the same resources. In contrast to SOEs, POEs emphasize economic returns, which generate a higher requirement for better management. Therefore, a better environmental quality could be achieved with greater private sector participation (Kikeri et. at., 1992; Schmid and Rubin, 1995).

2.1.2 Internalizing environmental externality

Although POEs may have higher efficiency in resource utilization, they may not seek to internalize environmental externalities (Baumol and Oates, 1988). In other words, the private sector may compromise the environment to avoid the potential cost of environmental investments and expenditures (Eiser, Reicher and Podpadec, 1996). However, the SOEs and COEs have their incentives to internalize the environmental costs resulting from their pollution discharge, in order to obtain higher national or local social welfare. While a country itself is heterogeneous in terms of its geographic, economic and social characteristics, the environmental damage and the internalization of pollution externality within a region are obviously different from that within a nation. However, no empirical studies have been conducted on the existence of the possible behavior of internalizing environmental externalities.

2.1.3 Bargaining powers in regulatory enforcement

Environmental bargaining power is defined as an enterprise's capacity to negotiate with the local or national environmental agencies pertaining to the enforcement of pollution control regulations such as pollution charges, fines, etc. Due to the difference of ownership structures, enterprises may have significantly differentiated impacts on the local or national economy and politics, or they may have different relationships with the local environmental authorities and governments. These differences can lead to the different levels of bargaining power. For example, SOEs in China have strong connections with the governments and some managers of SOEs have higher political status than the local environmental authorities. As a result, SOEs are able to elicit a lower pollution payment or punishment; and they have less incentive to decrease their pollution and reduce the pollution intensity. Similarly, COEs in China are strongly connected with the local governments, and they are also equipped with relatively higher environmental bargaining powers in contrast to the private enterprises. Wang et al. (2001) have empirically demonstrated the lower bargaining power of POEs as compared with SOEs and COEs.

Bargaining powers with communities

Firms with different ownership may receive different levels of informal regulation, or community pressure, on pollution abatement. Informal regulation may always exist whether or not any formal regulation is present or effective in developing countries. In this view, local communities may have struck their own Coasian bargains with neighboring plants. Leverage in negotiations is provided by social pressure on workers and managers, adverse publicity, threat of violence, resources to civil law, etc. The effect of community pressure on emissions has been confirmed in several empirical studies (Pargal and Wheeler , 1996; Wang, 2000), which found that proxies for direct community pressures (community income and education levels) have significant effects on plant level emissions. Dasgupta and Wheeler (1996) show that there is a significant correlation between the number of complaints and the pollution emission, and consequently the quality of environment. But whether a community takes environmental action or at what level the informal regulation and community pressure are effective to pollution control, possibly depend on the impacts of a certain enterprise on the regional economy. There is an inherent trade-off by local residents in choosing an optimal pressure level to impose on a certain enterprise taking into consideration the potential economic benefits from their job opportunities, income expectations, and the environmental and social costs of production externalities.

FDI with better technologies

Foreign direct investment in developing countries may, or may not, generate more pollution. The increase of foreign direct investment and an emergence of foreign companies and other joint ventures in developing countries naturally raise the question about whether the "pollution havens" hypothesis[4] holds. If it holds, then more severe industrial pollution and environment degradation will be a result of an increase of direct foreign investment and plant re-allocations (Kalt, 1988; Low and Yeats, 1992; Xing and Kolstad, 1996; Mani and Wheeler, 1997). However, most of the empirical studies do not find significant evidence to support the hypothesis including the comprehensive survey by Dean (1992). Rather, FDIs generally hold advanced technologies, and therefore, the environmental performance of FDIs may be better than domestic enterprises.

The direction and the level that ownership structure can affect environmental performance depend on the magnitudes of the effects summarized above. A few of the empirical studies have tested the relationship between the ownership structure and environmental performance (Anderson, 1995; Kikeri, Talukdar and Meisner, 2001). Particularly, Talukdar and Meisner (2001), using annual data for 44 developing countries from 1987 to 1995, show a significantly negative relationship between the degree of private sector involvement in terms of its investment in the total domestic investment, national GDP, or its value of output share in the national GDP, and CO2 emission levels. A conclusion drawn from this study is that an increased role by the private sector in an economy is more likely to help the environment of the economy. There are some very recent empirical investigations into the relationship between ownership and environmental performance at the factory level (Wang and Wheeler, 2000). These studies show that SOEs are more likely to pollute than private enterprises.

[4] The pollution haven hypothesis states the possibility of pollution-intensive activities re-allocating to developing countries with less stringent environmental standards.

2.2 A Theoretic Analysis

To analyze the differences in the environmental performance of industrial firms with different types of ownership, one may group firms into three categories: SOE, COE and POE, as defined before. Foreign companies may be viewed as private companies because they share the same profit maximization objectives. Joint ventures may have mixed ownership and their environmental performance may be in between.

A company's pollution discharge decision may be modeled by assuming that the company is to minimize the total cost subject to an output constraint. The total cost has three components: 1. total cost of factor inputs within the company, including the pollution abatement cost; 2. total pollution discharge penalty paid to the government authorities; 3. total pollution discharge damage incurred by society. For private companies, the first two components are real costs to them and they may treat the third component as zero. For collective or community companies, the social damages may be included in their objective function but may be considered only up to the extent where the local communities are concerned. However, for state owned companies, the total social damage to the whole state may be considered.

The production and pollution abatement decisions can be made by solving the following optimization problem:

$$\min_{X} w_X X + \alpha(I)P(Z) + \gamma(I)D(Z) \quad \text{s.t. } Y(X,I) \le y$$

$$\gamma(\mathrm{I}) = \begin{cases} 0 & & \text{if } I = 1(\textit{for}\ \text{POE}); \\ \mathrm{D}_i(\mathrm{Z}) / \mathrm{D}\ (\mathrm{Z}) & \text{for } i = 1,2\ldots & \text{if } I = 2(\textit{forCOE}); \\ 1 & & \text{if } I = 3(\textit{forSOE}). \end{cases}$$

$$\mathrm{D}(\mathrm{Z}) = \sum_i D_i(Z)$$

where I represents ownership with I=1 for POE, I=2 for COE and I=3 for SOE;
X is a vector of factor inputs with a price vector of Wx;
Z is pollution discharge which is a function of X and I; i.e., Z=Z(X, I);
P(Z) is the total penalty caused by the pollution discharge as regulated by the government;
D(Z) is the total environmental and health damage caused by pollution discharge Z;

$D_i(Z)$ is the total damage generated by pollution discharge Z upon community i where a COE belongs to; and y is the output.

$\alpha(I)$ represents the fact that firms with different types of ownership may receive different penalties even with the same pollution discharge Z; $\gamma(I)$ represents the fact that different firms may internalize pollution externalities differently. A private company does not consider this component, and a collective company only considers damages to their own community, while a state owned company may internalize the damage to the whole nation. The ownership variable I is also included in the production function Y (X, I), which reflects the differences in production efficiency with different ownership. $0 <= \alpha(I) <= 1$, and $0 <= \gamma(I) <= 1$.

The optimal level of input x is given by the following first-order condition:

$$\underbrace{w_x}_{\substack{\text{market price}\\ \text{of factor input}}} + \underbrace{\alpha(I)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x,I)}{\partial x}}_{\substack{\text{marginal cost}\\ \text{of pollution penalty}}} + \underbrace{\frac{\partial(\gamma(I)D(z))}{\partial z}\frac{\partial Z(x,I)}{\partial x}}_{\substack{\text{marginal environmental}\\ \text{damage internalized}}} = \underbrace{\lambda\frac{\partial Y(x,I)}{\partial x}}_{\text{marginal production}}$$

where λ is the Lagrangian multiplier. For a state owned company, the optimality condition of x is achieved when the value of marginal production equals the total marginal price, which equals the summation of the market price, the marginal environmental penalty to the company and the marginal damage to the society. For a collective company, the marginal damage is only considered up to its hosting local community, while for a private company, the environmental damage part is not considered at all.

In the following, the first-order condition will be employed to analyze the effects of production efficiency, regulatory bargaining power and internalization of environmental externalities on the environmental performance of POEs, COEs and SOEs. During the analyses, the following assumptions have been made:

a. Others being equal, an input with a lower total marginal price will be utilized more;

b. The marginal cost of pollution penalty is positive; i.e., $\frac{\partial P(z)}{\partial z} > 0$;

c. The marginal cost of pollution damage is positive; i.e., $\frac{\partial D(z)}{\partial z} > 0$;

d. $0 <= \alpha(I), \gamma(I) <= 1$.

2.2.1 Regulation Effects

Assuming that the difference in environmental performance is only from regulation. This implies that the efficiency effects and the internationalization effects are assumed to be zero or the same for all different types of ownership. Then, when the internalization effect is zero, the marginal price of the same input for companies with different types of ownership would be as follows:

$$MC1 = Wx + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} \quad \text{for POE}$$

$$MC2 = Wx + \alpha(2)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} \quad \text{for COE}$$

$$MC3 = Wx + \alpha(3)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} \quad \text{for SOE}$$

Where 1 is denoted for POEs, 2 for COEs and 3 for SOEs. The differences between the marginal prices will be only in the coefficient $\alpha(I)$. For a private company, the coefficient would be the highest, and close to 1. A state owned company may have the lowest coefficient. Thus we have: $\alpha(1) > \alpha(2) > \alpha(3) > 0$.

For inputs with positive marginal pollution discharges, i.e., $\frac{\partial Z(x)}{\partial x} > 0$, the marginal prices of the inputs are the highest for a private company. Less inputs would be used, and therefore less pollution would be emitted by a private company. For inputs with $\frac{\partial Z(x)}{\partial x} < 0$, the marginal prices are the lowest for a private company, the therefore more pollution reduction inputs would be used. Ultimately, the environmental performance of a private company can be the highest.

For a state owned company, the situation is the opposite. More pollution generation inputs and less pollution reduction inputs would be used. Therefore, the environmental performance of a state owned company would be the worst. The performance of a collectively owned company would be in between.

In summary, if only government environmental regulations are considered, the environmental performance of a POE would be better than that of a COE, and a COE is better than a SOE. The primary reason is that the bargaining powers with government authorities are the strongest for SOEs and weakest for POEs.

2.2.2 Internalization Effects

Assume the strength of environmental regulation is the same for all companies, and the only difference in the marginal prices of inputs are caused by the internalization of the pollution externality. Then the marginal prices of the inputs will be as follows.

$$\text{MC1} = \text{Wx} + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x}$$

$$\text{MC2} = \text{Wx} + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} + \frac{\partial Di(z)}{\partial z}\frac{\partial Z(x)}{\partial x}$$

$$\text{MC3} = \text{Wx} + \alpha(1)\frac{\partial P(z)}{\partial z}\frac{\partial Z(x)}{\partial x} + \frac{\partial D(z)}{\partial z}\frac{\partial Z(x)}{\partial x}$$

Di(Z) is only a fraction of D(z), and therefore, $\frac{\partial Di(z)}{\partial z} <= \frac{\partial D(z)}{\partial z}$. For a pollution generating input, i.e., $\frac{\partial Z(x)}{\partial x}$>0, the marginal price for a state owned company will be the highest. But for a pollution reduction input, i.e., $\frac{\partial Z(x)}{\partial x}$<0, the price would be the lowest for a SOE. Therefore, a SOE would use more pollution reducing inputs and less pollution generating inputs, and it would be the best environmental performer. A collective company would be the second best, while a private company would be the worst.

2.2.3 Efficiency Effects

Efficiency is not included in the model above, but a conclusion about efficiency can be fairly straightforward. For an input x positively contributing to pollution discharge, i.e., $\frac{\partial Z(x)}{\partial x}>0$, a higher efficiency means a lower marginal discharge of such an input. For an input negatively contributing to pollution discharge, i.e., $\frac{\partial Z(x)}{\partial x}<0$, the higher efficiency means a higher marginal pollution reduction. Therefore a higher efficiency means a less pollution generation and a higher pollution reduction, and finally better environmental performance. If POEs have higher efficiencies than COEs and SOEs, the environmental performance of POEs would be the best.

2.2.4 Combination and Discussion

Situations would be complicated if all of the above determining effects are combined. The differences in environmental performance of firms with different types of ownership are generally unpredictable, and the results would be an empirical issue.

While empirical studies have been conducted on the efficiency effect and the regulation effect, no studies so far have been completed on the existence of the internalization of environmental externalities. However, a testable hypothesis can be constructed in the following.

Without considering the possible internalization of environmental externalities by SOEs and COEs, the environmental performance of POEs should always be superior to that of SOEs and COEs, because both the efficiency effect and the regulation effect are positive with POEs' environmental performance, when all other factors such as technology, scale, sector, etc. are the same. Only the existence of internalization effect can make the environmental performance of SOEs and COEs better than that of POEs. If this is correct, then a finding that the performance of SOEs or COEs to be better than that of POEs could mean the existence of the internalization effect.

The empirical study on China presented below does show that the environmental performance of COEs are better than that of POEs, which could imply that those community owned enterprises do consider the possible pollution damages they generate to society in their decision making process.

III. China Survey and Statistics

To investigate the ownership effects on environmental performance, an enterprise level survey has been conducted in China. Before presenting the survey and the survey statistics, the following provides some background information about the industrial pollution control in China.

3.1. Policy Background

China's industrial growth has been extremely rapid in the past two decades. The annual growth rate has been about 15% in the 1990's. This has lifted tens of millions of people out of poverty. However, serious environmental deterioration has accompanied this rapid growth. Many cities in China have been among the worst polluted urban areas in the world[5].

China has been adopting various policy measures to control industrial pollution[6], which include command-and-control approaches, administrative measures, economic instruments, as well as public information and campaigning. New sources are subject to environmental impact assessment policy and "three simultaneous" policy, which requires pollution abatement facilities be designed, installed and operated simultaneously with industrial production process technologies. Pollution discharge standards have been designed and implemented for different industries, different pollutants and different areas. Air, water and land have been classified into different zones according to environmental sensitivities, where different ambient and discharge standards are enforced.

[5] For more information, see World Bank (1997 & 2001).
[6] For more detailed discussions, see Sinkule and Ortolano (1995) and World Bank (2001).

The pollution charge has been one of the most important pillars of the industrial pollution regulatory system in China. This policy instrument was originally designed to promote compliance with pollution discharge standards. The Chinese environmental protection law specifies that "in cases where the discharge of pollutants exceeds the limit set by the state, a compensation fee shall be charged according to the quantities and concentration of the pollutants released." In 1982, after three years of experimentation, China's State Council began a nationwide implementation of pollution charges. Since then billions of yuan (US$1 = 8.2 yuan) have been collected each year from hundreds of thousands of industrial polluters for air pollution, water pollution, solid waste, and noise. In 2000, the system was implemented in all counties and cities. Five billion yuan were collected from more than half a million industrial firms; and numbers are increasing each year. Although studies have been conducted to reform the levy system with most analysts recommending an increase in China's pollution charge rate, few empirical analyses have actually investigated the polluters' response to the existing charges. In Wang and Wheeler (2002), province-level data on water pollution was analyzed and it was found that China's levy system had been working much better than previously thought. The results suggest that province-level pollution discharge intensities have been highly responsive to provincial levy variations.

3.2. Survey Design and Implementation

To study the pollution control behavior of Chinese industries and to investigate the ownership effects on environmental performance, we conducted a plant-level survey in China in the year of 2000. Three areas (Northern Tianjin, Danyang, and Liupanshui) were selected to conduct the survey. These three areas were selected because of their wide differences in social, economic and environmental conditions (see table 1), their significances in collective and private sector development, and their governments' support for conducting the research. Danyang municipality is located in a relatively rich, southeast province, Jiangsu province, while Liupanshui municipality is a part of a poor southwest province, Guizhou province. The northern part of Tianjin was also selected for this study, which is a relatively more urbanized, rich area, where the environmental situation is more serious than other two areas because of its dense population, even though the absolute quality is in between.

All major industrial polluters in each area were included in the sample. Plant-level information was collected from three channels. The first source is the municipal environmental protection agencies. All polluters are required to register each year their pollution related information with the local environmental authorities. Various ways, including surprise inspections and material balance estimation, etc., have been practiced by the local authorities to check the accuracy of their data. A questionnaire was also designed and implemented to collect information for those variables which were not included in the pollution registration practice. Personnel responsible for a plant's environmental management were required by the local authorities to submit the information. A plant manager survey was also conducted to collect subjective information on perceptions and attitudes toward environmental quality, policy enforcement, as well as environmental services.

The survey was conducted between April and September, 2000[7]. Detailed information was collected from 905 industrial plants. Plant surveys were distributed by three survey coordinators in each of the three areas. Returned surveys received quality checks from the survey teams before they were recorded into computer for analyses. Manager surveys were conducted by interviewers. Plant managers were summoned to the designated interview sites by the local environmental authorities, but the questionnaires were finished anonymously without government officers observing the interview process.

3.3. Statistics

Table 2 shows the number of industrial enterprises included in the sample, by survey site, ownership as well as industrial sector. SOEs and private enterprises took the largest proportions

[7] The data collection work was supported by the World Bank and China State Environmental Protection Administration (SEPA). Local environmental protection authorities in the three survey areas participated in the survey design and implementation processes. The survey teams were comprised of researchers from SEPA's Policy Research Center, Nanjing University, Beijing Normal University, as well as Guizhou Provincial Institute of Environmental Protection. The team members participated in the survey design and questionnaire pretests, were trained by the principal investigator, a survey expert, and conducted the survey.

in the Liupanshui sample, while collective enterprises accounted for approximately 60% in Northern Tianjin and Danyang samples. There were more private companies and less SOEs in Danyang than in the Tianjin sample. Tianjin and Danyang were mainly engaged in the chemical sectors; while Liupanshui had a higher proportion in the mining industry. SOEs in the sample were highly concentrated in mining and chemicals, while foreign companies were more engaged in textile and metal industries, and joint ventures in the chemical and equipment sectors.

Table 3 presents the statistics of major economic and environmental variables. It is clear that the SOEs are generally bigger than other types of companies, while the private companies are the smallest in terms of scale. While there were much higher investments in pollution abatement facilities with SOEs, operation expenditures with collective enterprises were much higher than other types of industries.

Pollution discharge intensities and concentrations are given in Table 4. For air pollution (SO2 and TSP), the SOEs' intensity is much higher than other types of companies. Collective enterprises have higher TSS intensity for water pollution. In terms of concentration, the water pollution discharges from the private companies are the highest. The performance and compliance information are presented in table 5. SOEs violated the emission standards the most. SOEs and the joint ventures, most of which have SOE components, are among the worst performers. Collective enterprises have the lowest violation rates.

Table 6 shows that private companies received environmental inspections the most, even though the scales of private companies are among the smallest (table 3). More SOEs and private companies received citizen complaints on pollution issues (table 7). The levy payment ratios of SOEs are lower than the collective and private companies (table 8). More SOE managers feel that the enterprises are damaging the environment and that there are strong pressures from the government and the communities to further abate pollution (table 9).

IV. Econometric Analyses

The survey statistics presented in last section demonstrate the differences in environmental enforcement and performance of Chinese industries with different types of ownership. In this section we further investigate the determinants of environmental performance, focusing on the roles of ownership.

4.1 The models

Performance indicators selected for the analyses in this study are pollution discharge intensities. Based on previous studies (e.g., Pargal and Wheeler, 1996), the following sets of determinants are identified and included in the analyses:

(1) Environmental policy and external pressure

Variables in this category include the pollution charge rate, inspections, citizen complaints, as well as dummy variables for environmental zones where environmental standards are less restrictive if an enterprise is located in an industrial zone. Average charge rates (charge per unit of pollution discharge), average complaint rates (complaints per company) and average inspection ratios (inspections per company) in the year before (i.e., 1998)[8] at the town level (the lowest government unit in China) are used in the econometric models, and they are expected to have negative impacts on pollution discharges.

(2) Input prices

Prices of water use, electricity, coal and wages may also affect pollution discharge. Depending on whether or not they are substitutes or complements to pollution abatement, they may affect the pollution discharge positively or negatively.

(3) Characteristics

This set of variables includes the sector, vintage, scale, location as well as ownership. Ownership is the focus of this analysis, which includes SOEs, collective, private, foreign as

[8] Data in the year of 1998 are used in order to control potential endogeneities.

well as joint ventures. The level of technology is difficult to acertain in this context and is not available for this analysis. However, the possible technology effect can be expected to be controlled by the inclusion of sector dummies, vintage and scale.

4.2 The Results

Table 10 presents the econometric estimation results. Estimation results are provided for two conventional water pollutants: total suspended solids (TSS) and chemical oxygen demand (COD). The dependent variables are pollution intensities (pollution divided by value of output) in log terms.

The citizen complaint variable, an indicator of informal regulation, defined as complaints on water pollution received in 1998 in a town divided by the total number of polluting firms in the town, shows a strong negative impact on TSS intensity. The elasticity is about 1.7, which demonstrates the strong existence of informal regulation in China. The result on COD intensity is not significant, which is consistent with the understanding that citizens can only perceive pollutants such as TSS and that COD is not directly observable.

The pollution charge variable also shows strong, significant negative impacts on pollution intensities, which is consistent with previous empirical findings conducted in China (Wang and Wheeler, 2000 and 2002). The elasticity of the pollution charge with respect to TSS and COD intensities are 0.33 and 0.28 respectively. The visits of government officials to the polluting firms have a positive impact on COD intensity and an insignificant effect on TSS intensity. This is counterintuitive, if the visits are interpreted as the efforts of the government in enforcing the environmental laws. But if the number of visits represent a close relationship between government officials and the polluting companies, the story could be quite different. A further investigation on the nature of the official visits to the polluting companies in China seems warranted.

The input price variables show that the higher the water price, the higher the pollution discharge intensities, which is true for both TSS and COD. The price of electricity has a positive correlation with TSS discharge and negative correlation with COD discharge. This is consistent with the understanding that the consumption of electricity is positively related with TSS treatment, while the treatment of COD may not consume as much electricity. The price of coal is negatively correlated with TSS discharge, which could imply that a smaller consumption of coal, the less the TSS discharge. The worker's wage does not have any significant correlation with pollution discharge intensities.

For variables representing firms' characteristics, ownership does contribute to difference in pollution intensities. For TSS, SOEs[9] have the highest discharge intensities, followed by POEs, COEs and the FDIs and joint ventures. While the difference between SOEs and POEs is not significant, all others are statistically significant. However, results for COD are not significant. Scale effects are clearly shown for the two pollutants; the bigger the firms, the lower the pollution discharge intensity. The number of years in operation does not show a significant effect, while some water pollution intensive sectors give positive results. Plants located in industrial zones have higher pollution discharge intensities, which is consistent with the fact that pollution discharge standards in the industrial zones are less restrictive.

V. Summary

This study analyzes the ownership effects on industrial environmental performance. Economic efficiency, production and pollution abatement technology, willingness to internalize environmental externality, bargaining power with government as well as with community in environmental enforcement have been identified as the major reasons why firms with different types of ownership perform differently in terms of pollution discharge. The private sectors, both domestic and foreign invested in a developing country, may have higher economic efficiencies in resource utilization, but may have fewer incentives to internalize environmental externalities and less bargaining power in environmental enforcement. State-owned and collectively owned enterprises have a higher willingness to internalize environmental externalities and a higher bargaining power in environmental enforcement, however the economic efficiency may be lower. Therefore the overall ownership effect is an empirical issue.

[9] SOE is a default variable in the model.

The empirical study conducted in China provides consistent results with the theoretical analyses and the previous empirical studies. The results show that state-owned enterprises have the worst environmental performance, with the domestic private enterprises as second. The best performers are foreign companies which have the lowest pollution discharge intensities.

The Chinese collectively owned enterprises have a significantly better performance in pollution reduction than the domestic private sector. If management efficiency with the private sector is not lower than the collective sector, which is generally believed to be true, this empirical result could imply the existence of the phenomenon of internalizing environmental externalities with the collectively or community owned enterprises, since other possible performance determinants have already been controlled for in the model.

The study also finds that the pollution charge instrument is effective in terms of providing incentives for pollution reduction. This is confirmed by previous empirical studies. Citizen complaints are found to have a strong positive role in pushing polluters to reduce pollution discharges. This shows a great potential to use community pressure approaches to promote industrial pollution control in China.

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Table 1. Sample Areas

Sample area	**Liupanshui**	**Tianjin**	**Danyang**
Per Capita GDP (yuan)	2,700	15,900	16,100
Average workers' wage (yuan)	5,700	6,800	6,900
SO2 concentration (ug/m3)	75.9	23.3	25.2
TSP concentration (ug/m3)	134.2	158.4	231.6

Table 2: Sample Structure by Ownership and Sector

	By Ownership						By Sector			
Location	SOEs	Collective	Private	Foreign	Join	Total No.	Mining	Chemical	Mental	Water, gas & power
Guizhou (LiuPanshui)	99 (36%)	41 (15%)	122 (44%)	2 (1%)	12 (4%)	276	104 (38%)			47 (17%)
Tianjin	39 (15%)	159 (61%)	27 (10%)	6 (2%)	28 (11%)	259		41 (17%)	40 (17%)	
Jiangsu (Danyang)	21 (7%)	185 (60%)	82 (27%)	3 (1%)	16 (5%)	307		68 (22%)	47 (15%)	
Total	159 (19%)	385 (46%)	231 (27%)	11 (1%)	56 (7%)	842	106 (13%)	116 (14%)		

Table 3: Economic and Environmental Profile by Ownership (in 1999)

Category	Variable	SOE	Collective	Private	Foreign	Joint Venture	Total average	N
Economic variables	Output value: *10 million yuan*	6.3 (17.7)	2.0 (6.1)	1.3 (5.3)	3.6 (3.6)	4.6 (8.6)	2.8 (9.4)	744
	Total value of assets: *10 million Yuan*	24 (175)	1.0 (5.1)	0.5 (1.9)	1.2 (1.3)	15.6 (77.2)	6.2 (78.4)	790
	Employment: *Persons*	986 (2191)	151 (331)	118 (357)	326 (516)	256 (363)	307 (1049)	821
Environmental variables	Fixed environmental assets: *10,000 Yuan*	686 (3706)	77 (458)	21 (112)	10 (15)	297 (1334)	194 (1735)	630
	Environmental investment: *10,000 Yuan*	324 (1231)	51 (492)	4 (10)	0 0	8 (18)	77 (602)	439
	Environmental Operation costs: *10,000 Yuan*	34 (122)	16 (173)	3 (21)	2 (2)	10 (26)	16 (130)	486
	Waste water treatment facility: *set*	1.52 (0.86)	1.09 (0.44)	1.17 (0.89)	0.75 (0.50)	1.07 (0.39)	1.22 (0.70)	204
Pollution Discharges	TSS: 1000 *tons*	16.8 (77.5)	9.5 (104.3)	3.4 (39.6)	8.1 (22.8)	22.4 (111.7)	10.1 (84.1)	641
	COD: 1000 *kg*	165.6 (794.1)	8.1 (33.6)	7.6 (45.2)	1.3 (3.1)	13.9 (39.9)	41.2 (369.6)	635
	SO2: *tons*	274,243 (2948,465)	277 (2,812)	34 (186)	72 (156)	14,382 (87,573)	55153 (1310199)	608
	TSP: *tons*	1925 (6969)	0.71 (1.15)	3.18 (8.17)	0.06 (0.10)	1.00 (1.14)	391 (3145)	69

Note: Data are averages by category. Standard variances are shown in the parentheses.

Table 4: Pollution Intensity by Ownership

Variable	Intensity of labor				Intensity of output				Emission concentration			
Unit	Ton/person				Ton/ 10,000 yuan				μg/l		μg/m3	
Pollutant	TSS	COD	SO2	TSP	TSS	COD	SO2	TSP	TSS	COD	SO2	TSP
SOE	16.8 (129)	144.1 (97)	19.4 (88)	0.7 (76)	2.5	21.4	3.2	0.2	310	353	2097	440
Collective	34.9 (56)	119.8 (97)	1.2 (41)	0.01 (17)	2.9	8.2	0.11	0.0	178	282	1426	124
Private	15.8 (50)	115.9 (77)	0.5 (40)	0.3 (5)	1.6	11.2	0.06	0.1	956	426	2548	113
Foreign	0.0 (9)	11.2 (9)	0.4 (9)	0.0 (9)	0.0	0.1	0.03	0.0	288	168	3018	150
Joint venture	5.2 (16)	63.9 (21)	0.3 (16)	0.02 (4)	0.1	1.1	0.01	0.0	142	114	1258	150

Note: The numbers of firms by ownership are shown in the parentheses.

Table 5: Environmental performance and compliance by ownership (%)

	violated emission concentration standards	exceeded emission quota	did not pay their levies on time	did not submit their emission report	Discharge outlet did not meet standard	did not assess their environmental impact	did not have specific environmental staff
SOEs	64	80	47	42	45	61	62
Collecitve	45	44	40	39	40	44	48
Private	44	63	28	26	50	60	56
Foreign	40	50	60	50	50	50	70
Joint	60	64	60	60	60	61	65
Total	49	58	40	37	40	53	54

Table 6: Average numbers of inspections over all the sampled firms

	SOE	Collective	Private	Foreign	Joint Venture	Total average
National Inspections	0.11	0.05	0.05	0.10	0.10	0.06
Provincial inspections	0.62	0.26	0.26	0.10	0.30	0.33
Municipal, County and Town Visits	2.98	1.71	3.54	1.54	1.77	2.45
Regular Visits	3.35	3.62	8.16	2.18	2.93	4.76

Table 7: Citizen complaints

		SOEs	Collective	Private	Foreign	Joint Venture
Percent of firms who received complaints	Water pollution	4.40	0.78	2.60	0	1.79
	Air pollution	2.52	1.04	1.73	0	1.79
Average Number of complaints	Water Pollution	0.39	0.01	0.16	0	0.13
	Air Pollution	0.09	0.03	0.02	0	0.09

Table 8:Levy Payment (actual payment/required payment)

	SOEs	Collective	Private	Foreign	Joint	Total
Levy payment for wastewater discharge	0.77	0.85	0.88	0.60	1.00	0.86
Levy payment for air pollution	0.69	0.72	0.80	1.00	0.81	0.74
Levy payment for solid waste	0.00	0.50	1.00	1.00	N.A	N.A

Table 9: Managers' Self-evaluation of Environmental Performance and Pressure

(% of yes)

	Ownership					
Question	SOEs	Collective	private	Foreign	Joint venture	total
Damaging environment?	55	34	36	13	46	40
Meet requirements?	89	89	74	80	93	85
Better than others in the same sector?	64	63	48	87	62	62
Pressure from communities?	71	59	48	60	43	42
Pressure from government?	78	33	36	47	31	31
Total number of firms	221	379	231	15	59	905

Table 10: Estimation Results of Pollution Intensity Equations [a] of TSS and COD

Variable name and description		TSS	COD
Ownership:	Collective	-0.63*** (-2.06)	-0.04 (-0.15)
	Private	-0.15 (-0.46)	0.23 (0.71)
	Foreign and joint venture	-0.91*** (-2.14)	-0.07 (-0.16)
Policy variables:			
Complaint (town average in 1998)		-1.69*** (-3.56)	0.25 (0.53)
Official Visit (town average in 1998)		0.06 (0.23)	0.89*** (3.34)
Levy (town average in 1998)		-0.33*** (-3.78)	-0.28*** (-3.28)
Input price:	water price	1.43*** (4.63)	0.99*** (3.20)
	electricity price	1.51*** (4.04)	-0.76*** (-2.04)
	coal price	-1.31*** (-2.99)	-0.09 (-0.22)
	worker wage	0.32 (0.90)	-0.15 (-0.43)
Scale:	fixed capital	-0.22*** (-4.08)	-0.17*** (-3.23)
Technology:	years of operation	-0.10 (-0.69)	0.21* (1.47)
Location: **Industrial zone**		1.89* (1.29)	0.30* (0.80)
Sector:	Mining	0.78*** (2.07)	0.30 (0.80)
	Food	1.68*** (3.94)	1.45*** (3.48)
	Textiles	-0.16 (-0.36)	0.41 (0.01)
	Leather	1.03 (0.87)	0.70 (0.59)
	Fiber	0.82 (0.78)	-1.52* (-1.46)
	Paper	3.64*** (3.50)	1.74** (1.67)
	Printing	0.04 (0.06)	1.00* (1.40)
	Petroleum	-0.83 (-1.14)	1.04* (1.43)
	Chemicals	0.24	0.28

	(0.74)	(0.86)
Pharmaceuticals	1.70**	-1.21
	(1.64)	(-1.17)
Rubbers	0.32	-0.73
	(0.40)	(-0.91)
Plastics	0.10	-0.56
	(1.25)	(-0.70)
Non-ferrous	-0.21	-0.07
	(-0.36)	(-0.12)
Smelting	0.16	-0.33
	(0.41)	(-0.84)
Mental	0.42	0.07
	(1.16)	(0.19)
Equipment	0.53*	0.08
	(1.33)	(0.20)
Power, gas and water	2.27***	0.88*
	(3.98)	(1.51)
Number of observations	517	517
Adjusted R-square	0.52	0.14

***, ** and * represented for 5%, 10% and 15% confidence level.
[a] pollution intensity is defined as pollution discharge / value of output.

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